Product Development: Imagines versus Practice

László Berényi[1], László Soltész[2]

[1]Institute of Management Science, Faculty of Economics, University of Miskolc, Miskolc-Egyetemváros, 3515 Miskolc, Hungary, laszlo.berenyi@uni-miskolc.hu

[2]Institute of Machine and Product Design, Faculty of Mechanical Engineering and Informatics, University of Miskolc, Miskolc-Egyetemváros, 3515 Miskolc, Hungary, laszlo.soltesz@emerson.com

Abstract: The increasingly agile environment requires quick responses, including technological solutions and project management decisions. Former investigations aimed to explore expert opinions about project success factors. This study enhances the investigations to student opinions for establishing a more comprehensive view of the critical issues. A harmonious collaboration based on agreed values and methods has been appreciated. The study used a survey among engineering and business students (n=155) about the success factors of product development projects. The goal was to explore their opinions and compare those with expert opinions. The results show that clear goals are considered very important by both groups. Project meetings, cooperation, and other soft factors are recognized as more important by the experts than by the students. The results confirm that the order of the opinions is significantly different. The cluster analysis marked three distinctive patterns of opinions. Improving the performance of the mixed project teams reflected in project success calls for action. Accepting the more professional approach the experienced project team members, the lack of students' competencies can be designated. Changes must be supported by training activities and rethinking the curricula in the field.

Keywords: new product development; project success; student opinion; IPA analysis

1 Introduction

The Oslo Manual 2018 [1] defined product and business process innovations by the object. These two objects must be interrelated with each other in practice. New product development and performance improvement of current products (including services) can be considered the initial point of finding diffusion opportunities and adjusting business processes. It is to note that from a businessman's viewpoint, the process changes may provide input for the directions of product development. A special process is the product development process since both product and organizational-level benefits become available by rethinking it. Product development literature agrees that challenges are enhanced, and the changes have accelerated in recent years. The accelerated changes lead to an unpredictable environment, quickly changing product requirements. Consequently, a shorter lead time for the new product. In a different interpretation, the intensity, extension, and predictability of the environment force a change in strategy [2], including the rethinking of product development. The PMI [3] describes the phenomenon of uncertainty that can appear as the uncertainty of the requirements and uncertainty of technical degree (Figure 1) and offers a map to select the appropriate selection of managerial tools.

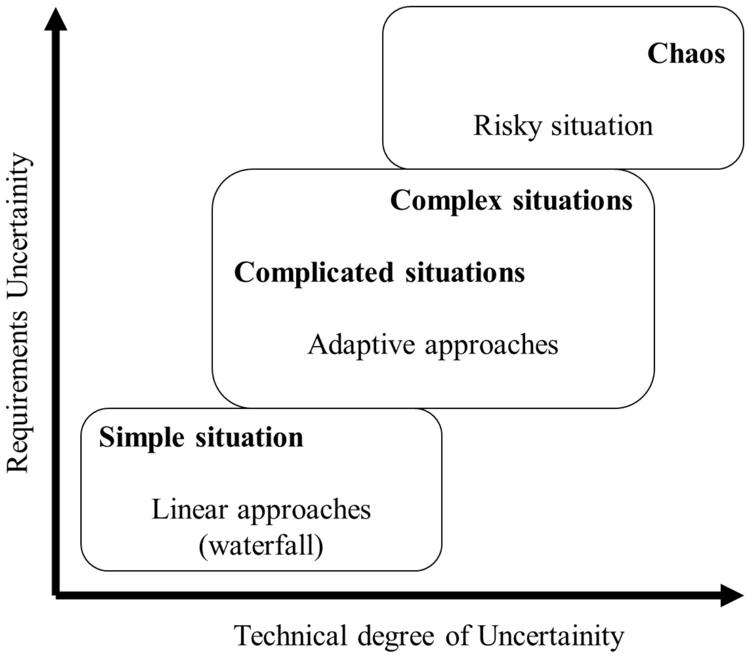

Figure 1
Applicable project management approaches by uncertainty (based on [3])

Baccarini [4] highlights the product success covering the organizational expectations as a success factor beyond the project management success. There is a change of focus point over time. The focus of attention has moved from project management success (in the 1960s–1980s) to project/product success (in the 1980s–2000s), then to project/product, portfolio, and program success and narratives of success and failure in the 21st Century [5].

Product development is usually managed by projects. Since its success goes beyond the project's outcomes, the organization's profitability or survival is in question; the classic iron triangle of project success (keeping time, keeping budget, delivering as planned) is not sufficient for understanding the success. Pollack et al. [6] show that the interpretation and the content of the triangle have been changing over time. They conclude that project success can be derived from the client's satisfaction with the outcomes and impacts. Contributing to corporate strategy and stakeholders' satisfaction must be considered [7] [8]. Validation of many aspects derived from corporate and stakeholder-level expectations is a restraint of project management. In the case of product development projects, the forced lead time reduction is decisive, which requires a renewed approach to the process [9]. Regardless of the industry and the purpose of the project or the composition of the project team, project management remains the application of knowledge, skills, and techniques to project activities to meet project requirements [3]. The project manager is the person who is responsible for coordinating the related activities in all circumstances.

The new conditions affect the related project management approaches and methods [10]. The strengthening of design thinking methods [11] [12] [13] supports the appropriate responses of the product development teams to the challenges. Agility in project management seems to become general, even beyond software engineering [3] [14] [15] [16], and the values and methods appear in the product development approach as well. Product development models shifted gradually from the traditional predictive to an iterative or incremental project approach; however, the development is ongoing.

The emergence of new information technologies and their impact on the business model is admitted by the Oslo Manual [1]. The spread of information technologies also forces the development of new products and business models. Ultimately, these technologies determine the new models of product development.

Over and above the technical issues, one more enabler must be considered for the success of product development: competent human resources. The reduced lead time and the shorter product life cycles lead to an intensified workload on the development teams. Corporate capacities must follow the expansion both in quantity and quality. Involving recent professionals and higher education students is fundamental for assuring the recruitment and selection of future staff. Moreover, novel ideas and improved dynamics can be presented in the projects. Nevertheless, this situation may amplify conflicts and require increased project management coordination efforts.

The Pneumobil competition [17] is an excellent example of managing a product development project with heterogeneous teams in all aspects. Students give the core of the project, and they have to work with professors, technical staff, and corporate experts. Success can be measured in speed and distance, but there is more behind performance than technical excellence. A successful Pneumobil team is a model of a successful project team. Actually, a Pneumobil project is a great simulation medium for product development projects. Beyond the deliverables, monitoring the teamwork and project management practices offers lessons for both the companies and the university. Understanding the motivations, communication, and collaboration can lead to an improved project management method as well as it will highlight the lack of education.

Our research contributes to exploring the differences in the approach of product development experts and students. The scope of the pilot study is limited to the judgment of engineering and business management students on the success factors of product development projects.

2 Product Development Process Approaches

The managerial framework of product development projects is usually moved from the traditional waterfall approach to iterative or incremental ones [3] [10] [18]. These approaches allow the redesign of the following steps depending on the progress and new information available. Integrated product development models reflect the accelerating changes and follow the opportunities of new technologies.

Olsson [19] published a pioneer model of integrated product development that emphasized project orientation and the role of teamwork in product development. Development phases (investigation of need, product principle, product design, product preparation, and execution) are derived from the recognition of needs and defined by professions, including marketing, operations, or finance. Andreasen and Hein [20] focused on the parallel design of product versions that were available through computer-aided design. Time-saving was available in a stable market environment. Meerkamm [21] carried on the idea of integration that required flexible organization and a new approach to design, the design for the product life cycle. The goal is to create a product that meets the requirements for the first try and is finished on schedule according to the plans. The approach corresponds to a narrower interpretation of the project success described by the iron triangle. Among the characteristic models defined by the PMI [3], the iterative life cycle is its counterpart. Ottoson [22] emphasized flexibility through framework thinking rather than traditional processes. This approach allowed a more effective response to the environmental changes for the project team and the organization. Incremental characteristics [3] can be found in the model.

Human competencies have emerged in the model of Ehrlenspiel [23], who forced exploiting human resources and promoted motivation. The suggestions are in line with the even more popular lean approaches [24] [25]. Magdeburg model [26] emphasized human-centered thinking and enhanced communication again. The collaboration of human and organizational resources with technology and methodology is justified by these models. These models present the processes as dynamic networks.

3 Expert Opinions about Project Success Factors in Product Development Projects

Project success and failure have extensive industry-specific literature with some elements of common thinking [27]. The emphasis has gradually moved from the success of project management (the 1960s–1980s) to project and product success (the 1980s–2000s). Portfolio and program [28] success has been appreciated recently [5]. Emam and Koru [29] identified the top project cancellation reasons. Although the investigations were focused on IT projects, similar problems are mentioned in other industries:

- senior management is not sufficiently involved,
- too many requirements and scope changes,
- lack of necessary management skills,
- over budget,
- lack of necessary technical skills,
- no more need for the system to be developed,
- over schedule,
- technology is too new; it does not work as expected,
- insufficient staff,
- critical quality problems with software,
- end users are not sufficiently involved.

A former analysis of the authors focused on the product development experts' judgment on the success factors of project management [9] [30] [31]. These questions provided the initial for a student-level survey designed to compare the two groups' opinions. The survey included success factors related to the followings:

- regulation,
- information management,
- the collaboration of the project team,
- the focus of the project manager.

Figure 2 shows the order of the success factors based on the responses of 112 experts based on [9].

The research found a high-level of agreement on a clearly written set of project goals, as a specification or scope, is really the most important need for projects. Justifying the findings of Ehrlenspiel and Meerkamm [32], the need for cooperation within the project team was confirmed, as well as the active focus of the project manager on the project team, regulation, and collaboration topics. The supporting role of knowledge management and information technologies is confirmed by the results [31].

Figure 2
Importance of product development success factors by experts (five-point scale, the higher values show more important items)

4 Research Design

4.1 Research Goal

The research aims to explore the students' opinions about product development projects' success factors and compare the results to expert opinions for supporting further development of product development. Additionally, the results may contribute to building harmonious partnerships between corporations and higher education institutions. The results are expected to serve the improvement of project management education by highlighting the lack of coherence in the knowledge level. Since the research has an explorative characteristic and we consider it a pilot study, no statistical hypothesis is formulated. The research questions are as follows:

- What factors do students consider relevant to product development project success?
- What are the differences in the perception of success factors of the product development project between the present and future generations?

4.2 Survey Design

A voluntary online survey was designed to collect information about students' approaches and opinions about product development processes. Data processing was anonymous; the mean values and the distribution of the responses give the basis of the conclusions. This study processes a highlighted question group about the success factors. The question is formulated as ‘How critical do you consider the following factors for the success of product development projects?’. The respondents were asked to indicate if there are any shortcomings in the area that will impair the project’s success. A five-point scale was used for the evaluation; higher values were asked to be marked if the respondent evaluated it harmful to the project if the item was corrupted or missing. The list of success factors investigated is based on the former survey among experts [9]:

- ☐ Clear, written project goal,
- ☐ Cooperation within the project team,
- ☐ Active focus on project team by the project manager,
- ☐ Project feedback meeting, collection of project lessons,
- ☐ Regular project meetings,
- ☐ Active focus on project deliverables by the project manager,
- ☐ Available written internal standards and regulation,
- ☐ Involvement of manufacturing experts into the product development project,
- ☐ Compliance with previously defined objectives and targets,
- ☐ Regular inspection of written standards.

4.3 Research Sample

The sample includes 155 responses from engineering and business students at the University of Miskolc in Hungary.

The data collection method was convenient, and the representativeness of the sample was not checked. Sample characteristics are summarized in Table 1.

Table 1
Students’ sample composition

		Percent
Gender	Female	47.7%
	Male	52.3%
Study type	full-time	40.6%
	part-time	59.4
Study level	bachelor	51.6%
	master	48.4%

4.4 Analysis Methods

The survey was designed for statistical analysis considering the instructions of [33] and [34]. According to the research goal and purpose, the focus of the study is exploring the characteristic patterns among the respondents. Although the measurement level of most questions allows the analysis of the distribution [35], the students' responses are presented per question also by the mean values considering its limitations and bias [36]. The reason for using the mean values is a simplified presentation of the results; variance analysis uses nonparametric methods procedure [37] [38].

The study presents the differences in the evaluations by students and experts; the related rank order is based on the mean values. The paper includes a two-dimensional visualization of the results. The visualization logic importance-performance analysis [39] [40] is applied to explore the agreement level between students and experts.

Exploring the patterns of opinions was performed by cluster analysis [41]. The two-step method of IBM SPSS [37] was selected for the database.

The statistical analyses were performed at a 95% confidence level. Data analysis used Microsoft Excel and IBM SPSS.

5 Results and Discussion

5.1 Students' Assessment Results

Available standards and regulations are considered the most important success factor of a product development project in the sense that students feel the project implementation is unattainable in the absence of this. Moreover, the following items in the ranking also belong to regulatory issues (Figure 3). The project management activity and regular project meetings are at the end of the relative order.

Figure 3

Critical factors by students' evaluation (5-point scale, the higher values show more critical items)

Gender (female, male), study level (bachelor, master), and study type (full-time, part-time) were used as grouping factors of the analysis. Females' evaluation shows higher values than males, and part-time students' evaluation exceeds full-time ones for each item. In the mirror of efforts to increase the share of female engineers [42], a detailed analysis is worthwhile in this field. The evaluation by study level does not show a clear pattern, and the values are close to each other. However, the Kruskal-Wallis analysis of variance shows significant differences in limited cases:

- Active focus on project deliverables by the project manager (x_{male}=2.28, x_{female}=2.78, Kruskal-Wallis H=3.889, d_f =1, sig.=0.049), by gender
- Compliance with previously defined objectives and targets ($x_{full\text{-}time}$=2.32, $x_{part\text{-}time}$=2.88, Kruskal-Wallis H=8.953, d_f =1, sig.=0.003), by study type
- Active focus on project deliverables by the project manager ($x_{full\text{-}time}$=2.19, $x_{part\text{-}time}$=2.75, Kruskal-Wallis H=5.450, d_f=1, sig.=0.020), by study type

The values of the item-level evaluations are close to each other, suggesting a kind of uncertainty in students' opinions about the success of product development projects. As extensive experience in project management cannot be expected among the respondents, this is not reprehensible. Despite the limitations of the results, the relative order on the sample can describe the assumptions and imaginations that are valuable information for developing related curricula and preparing the companies for what they will face when hiring beginners. According to the survey experience, the goals, standards, and regulations are trusted.

5.2 Results of Cluster Analysis

The student's evaluations of the product development project success factors were used to establish clusters in order to explore patterns. A dimension reduction was necessary since the nonparametric correlation coefficient values between the question are high and significant in each case (Spearman's Rho values are between 0.407 and 0.909). Based on the four factors explored by principal component analysis with Varimax rotation, the two-Step Cluster analysis of the IBM SPSS software allowed three clusters with a fair explanatory power (average silhouette measure of cohesion and separation is 0.3). Figure 4 compares the mean values of the responses by the clusters.

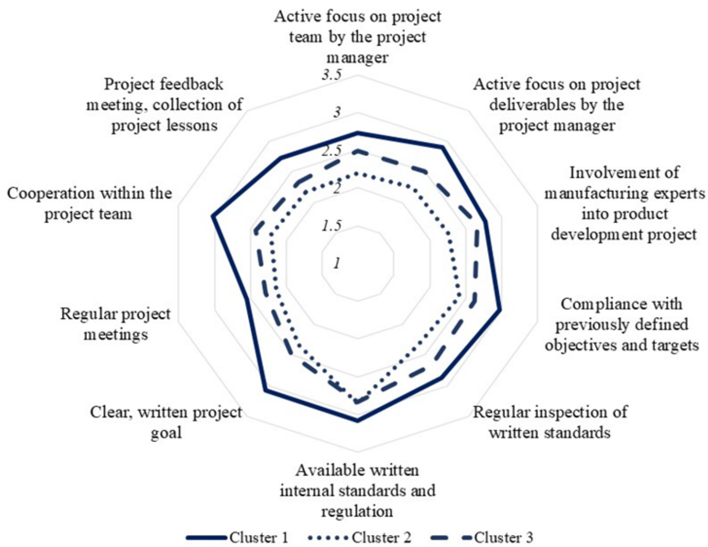

Figure 4
Cluster characteristics (5-point scale, mean values)

Cluster 1 (31.6% of the respondents) includes students with the highest ratings. They keep the factor more critical to project success than others. Outstanding values are found in the factors of project team cooperation, having a clear project goal, and the active focus of the project management on the deliverables. Cluster 2 (40.6% of the respondents) represents the middle way. In the case of Cluster 3 (27.7% of the respondents) show, the role of standards and regulation is dominant compared to other factors. They evaluated the failures in the listed success factors as less harmful than other clusters. The results confirm the general trust of students in the regulated procedures and the subordinate expectations about cooperation within the project team.

Cluster membership is checked for the grouping factors used in the survey by cross-tabulation, but no significant differences are found by gender, study level, or study type.

5.3 Comparing Student and Expert Assessment

The order of the mean values is shown in Table 2. The difference between expert and student evaluation is remarkable. The correlation coefficient between the rankings is at a moderate negative (ρ =-0.37) level, which suggests a lack of agreement. Figure 5 gives a visual representation and grouping of the results by the ranking orders.

Table 2

The ranking order of the evaluations

	Expert	Student
Clear, written project goal	10. the most important	8.
Cooperation within the project team	9.	5.
Active focus on project team by the project manager	8.	3.
Project feedback meeting, collection of project lessons	7.	2.
Regular project meetings	6.	1. the least harmful if failed
Active focus on project deliverables by the project manager	5.	4.
Available written internal standards and regulation	4.	10. the most harmful if failed
Involvement of manufacturing experts into product development project	3.	6.
Compliance with previously defined objectives and targets	2.	9.
Regular inspection of written standards	1. the least important	7.

There are only two items that are considered in the similar evaluation quarter by the experts and the students. The quarter in Figure 5 evaluated as important by the experts and less critical by the students include factors that cover the soft side of project management, such as the role of meetings or the personal focus of the project manager on the team as well as cooperation. Cooperation within the project team also belongs to this quarter. In addition, hard elements such as the role of written project goals, regulations, and inspection of the standards show just the opposite. These factors are considered more critical by the students than by the experts.

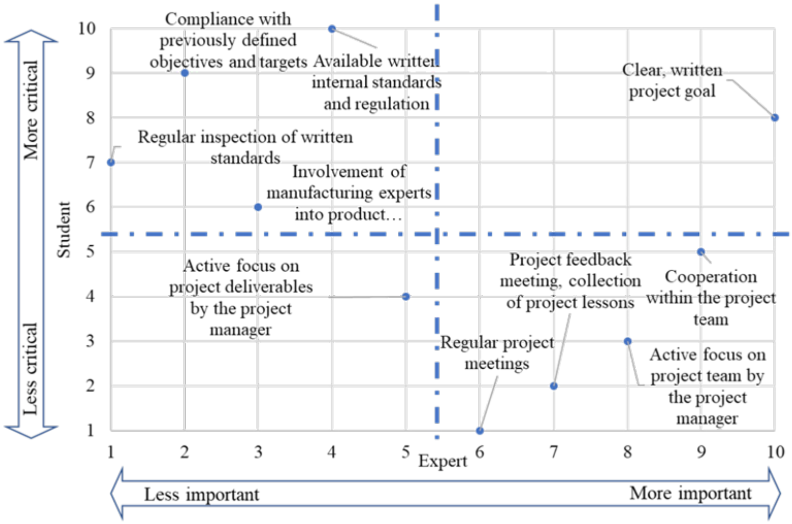

Figure 5
Visualization of joint results among expert and student

Conclusions

The unpredictable environment due to the accelerating technological and social changes force rethinking business processes. The pressure on product development can be tracked well in the improvement of the development models. The reduced market lead time of a new product requires additional resources from corporations that can be supported by involving higher education students. Sustaining team effectiveness needs understanding the similarities and differences in attitudes between the students and the corporate member.

According to the first research question about the relevant success factors considered by students, the belief in hard factors as standards as planning can be highlighted. It can be concluded that students imagine product development projects as manageable in a predictable way. The second research question aimed to compare the approach to project work between practicing professionals, and future project participants can provide profitable information. The survey results show remarkable differences between the opinions of the two groups. Students recognize hard factors of project success as more relevant, while experts value soft coordination tools as decisive. The experience of the study indicates the necessity for enhancing management education among engineering students (e.g., leadership, communication, problem-solving). The findings lead to a theoretical implication about the further directions of product development models. The option for collaboration is incorporated into recent methodologies, but it primarily aims for internal stakeholders, involving customers or procurement partners. Refinements should address students as future engineers and higher education institutions as knowledge sources.

Although the evaluation of the results is limited due to the sample composition, and the survey covers a pilot study of the problems, attention must be drawn to the improvement opportunities of engineering and management youth education. Product development projects involve a great variety of professional knowledge at a strenuous work pace. A common understanding of the values that drive project management is inevitable for assuring success at any interpretation level. Verifying the findings in other areas of specialization is necessary for generalizing the results.

Beyond improving the project management skills of students in general, the practical implication of the study is enhancing the cooperative programs between corporations and higher education institutions. Special projects, like Pneumobil projects, have a relevant student attendance and offer excellent opportunities for testing targeted project management training programs at low business risk.

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